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PRACTICAL KITES AND AËROPLANES

PRACTICAL KITES AND AËROPLANES

HOW TO MAKE AND WORK THEM

BY

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FORTY-THREE ILLUSTRATIONS

LONDON
GUILBERT PITMAN
CECIL COURT, ST. MARTIN'S LANE, W.C.
1903

PREFACE.

THE kite, from the toy of a schoolboy, has, by the ordinary laws of mechanical evolution, developed into the aëroplane, capable of carrying loads vertically, and sustaining them at a certain altitude by the ordinary wind currents, but so far the airships of the future as a problem admits of no solution by the aëroplane or aëro-curve surface alone; unless it may happen to a future inventor to cause a flat disc, of gas or air, which by its inherent high pressure shall impinge upon the inner surface of an aëro-curve, and by diversion overcome gravity, and thus cause a vertical ascension. This may occur in the future, but according to our present lights a captive aëroplane may be only used for raising a single passenger, to the height permitted by the tension rope or cord and the pressure of the air current prevailing in the atmosphere. For military and other signalling purposes such a kite or aëroplane is invaluable, because of its construction affording facilities in the way of transport, without the necessity for compressed gas apparatus. Further, the comparatively easy application of an electrically released stop for a camera properly constructed to give bird's-eye snapshots of the environment of an enemy's movements, is yet another advantage that tends to place the kite or captive aëroplane as a useful adjunct in war time.

In the more peaceful utilization of such a machine, we may tow and tack a boat upon an open river, or the sea, and under certain conditions, a car or sledge.

The real object of this little work is to place within the scope of the amateur aëronaut the laws governing the construction and the efficient operations of the kite or captive aëroplane as a really practical machine.

If I can create an interest in the conquest of the air, even by such simple methods as set out in the following pages, to the many workers and lovers of science who like to go out of the beaten track, and the level and even groove of conventional practice which ordains that the mechanical use of the unstable air against gravity is in some sense a blasphemy, I shall have attained my object.

It must be remembered that the sea is unstable, yet science has rendered it safe—indeed, safer than latter-day road traffic; and for many centuries the line of definition of the ocean horizon was, even to hardy navigators, an impassable boundary.

In conclusion, he that makes a carrying captive aëroplane has achieved the greatest difficulty in aërial navigation, that is, the "want of confidence." Had it not been for this, the most fatal of the obstructions to the conquest of Nature in this last branch of applied science, we should have been a quarter of a century ahead, and the generation of to-day floating in the air as they now do upon the water, without fear, and with greater enjoyment.

FREDK. WALKER.

OXFORD,
August 31, 1903.

PRACTICAL KITES AND AËROPLANES.

CHAPTER I.

THE familiar kite of schoolboy days, with its flexible tail formed of copy-book leaves, is well known, and is an instance of the hereditary conventualism of the Briton from boyhood to old age. To obtain the necessary equipoise, the tail with a tasselled terminal was all-essential, notwithstanding the fact that the Chinese for pastime only have been kite-fliers for twenty centuries, and have really combined a sport with artistic surroundings, always maintaining the aërial equipoise without the tail, whether the shape be lion, dragon, or eagle. Considering that during this period the Chinaman, conventional but sensible, has used a wheelbarrow with a central wheel, whilst we still perpetrate the mechanical iniquity of a wheel at one end, the tail of the kite is not remarkable as a survival. Now that the kite has departed from the regions of toydom, and has important functions to perform in the service of mankind, certain scientific deductions from experimental data determine the laws of construction for raising weights and preserving equipoise. It is within the province of this work to describe the dimensions and shape, with the best mode of constructing kites for ascertaining the state of the upper atmosphere, photographing, wireless sufficient and luminous signalling, and, for those possessing confidence, aërial flight.

A very fascinating book for youths was in general circulation about two-score years ago, entitled, "Up in the Air, down in the Sea." Like many of the well-known works of Jules Verne, the prolific inventive power of the novelist really foreshadowed the actual attainments of modern science. In the work to which I allude the hero converts the remnants of his wrecked balloon into a huge kite, and by this ascends and crosses a hitherto inaccessible mountain range. So far, everything is possible, but the author does not dispense with the tail—after the style of the schoolboy's *chef-d'ouvre.*

In 1826 Messrs. Pocock and Viney constructed a large tailless kite, which in these days would be termed an "aëroplane," and it was used to propel a four-wheeled carriage, called by the makers the "Charovolant." This novel motor-carriage performed a journey from Southampton to London, but unfortunately no accurate record exists of either area, load, speed, or weather.

In order to render the kite of real service it must be considered in the light of an aëroplane, which has a fixed fulcrum, a constant pressure, and a variable angle, which is varied in proportion to a load.

Therefore, taking A (Fig. 1) as a square of cardboard 1 ft. square, and the wind pressure represented by the arrow P, the point of support being *p*, and the cord forming the fulcrum C, the angle due to constant pressure P and area A being B C D—presuming that there is no motion in any direction, it is obvious that the air current due to P must recoil from the surface of A in the direction indicated by the smaller arrows. A vertical or screw motion is apt to occur, and A is twisted one way until the twisted cord exerts a force in the opposite direction, when the action is reversed. To remedy this a weight (W) is added, with a probable extension, as shown by the dotted outline, and by gravitation alters the angle of support. This

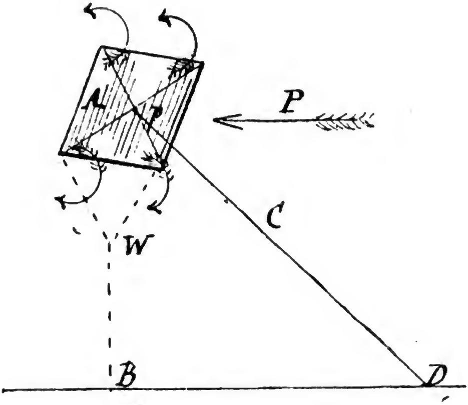


Fig. 1.

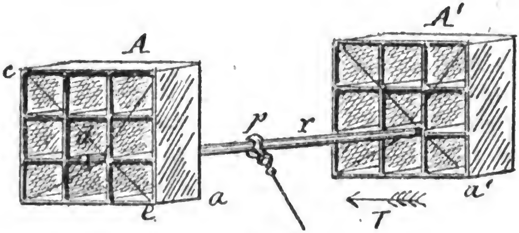


Fig. 2.

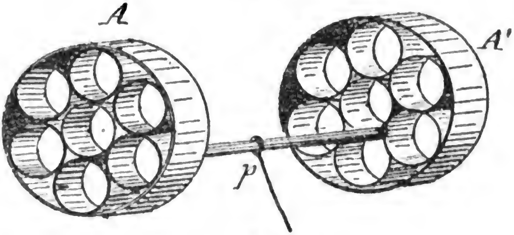


Fig. 3.

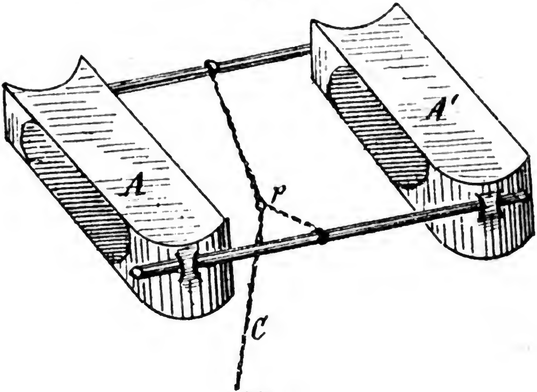


Fig. 4.

proves—first, that the weight (W), area (A), and angle (B C D) have relative values; and, secondly, that a rigid surface (A), with an equally rigid weight (W), has a tendency to set up an oscillatory movement, which increases until a complete revolution takes place, in which case the kite will dive downwards, under the conditions of the weight (W) being even momentarily above the fulcrum (*p*). Hence we see the reason of the flexible tail; but as we desire to dispense with the tail we must follow the lights afforded by recent improvements. Mr. C. Hargrave conceived the idea of a double cellular kite, the primary inception being shown by Fig. 2. Here we have two rectangular frames (A A′) divided into nine compartments, and joined by a light rod (*r*), the fulcrum being at *p*, and the air currents shown by P as before, the whole forming a perfectly stable kite, as is shown, but incapable of carrying an appreciable weight by reason of its equipoise being self-adjusted, according to constant pressure (P) and area (A). This equipoise is due to the air current (P) being cut by the edges (*a a′*), and thus diverted into the cellular compartments, each of equal area. It follows, therefore, that any upward or downward tendency on the part of A or A′ is counterbalanced by the opposite effect upon the other side. The shape may be varied by adopting a circular form (Fig. 3) or curvilinear shape (as Fig. 4). Two, three, or more kites may be sent up in tandem, as shown by Fig. 5, in which case a weight (W) may be supported.

Probably the simplest form of box kite for the

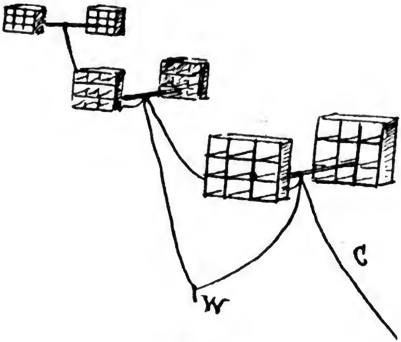


Fig. 5.

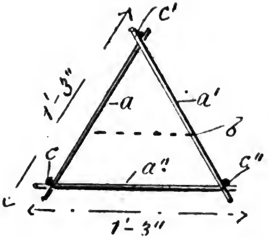


Fig. 8.

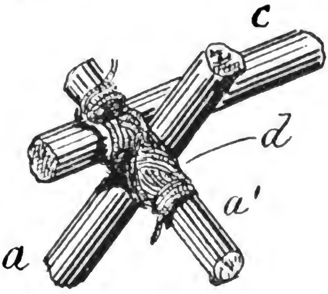


Fig. 10.

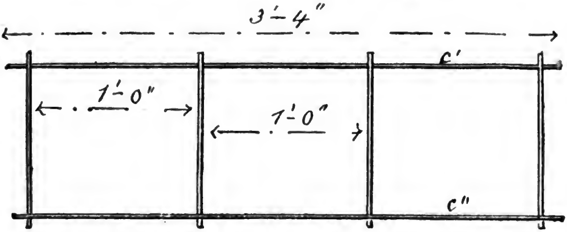


Fig. 9.

amateur to commence the construction of before more elaborate apparatus is attempted will be found by studying Figs. 8, 9, 10, and 11.

Take three tolerably straight lengths of "drain-cane," about $\frac{3}{8}$ in. diameter and 3 ft. 4 ins. in length. Next, of similar pieces of cane 15 ins. in length, make four triangles, as shown by Fig. 8, and temporarily lash them together by a turn or two of cotton thread. Now placing these 12 ins. apart, as in Fig. 9, the triangles formed by the members *a*, *a′*, *a″* may have the longitudinal members *c*, *c′*, *c″* laid into position as shown, and there lashed, by means of cobbler's waxed thread, scaffold-pole fashion, as shown by Fig. 10. A touch of indiarubber solution, and the proximity of a heated iron, such as a kitchen poker (without contact), secures the joints. Now each box (A A′, Fig. 11) is covered with undressed calico, or even paper, although this last is not to be recommended. The central partition *b* requires no frame, and is, if calico be used, simply hemmed, and stitched between the sides of the boxes, as indicated

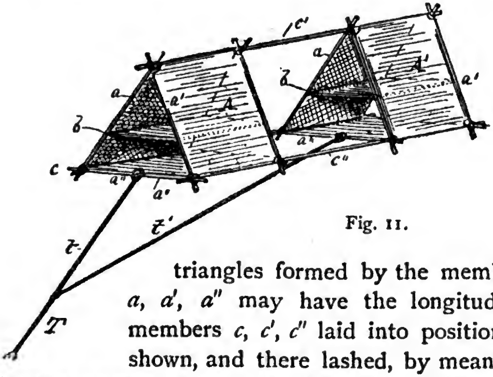


Fig. 11.

by the dotted lines. It is not absolutely necessary that the divisions *b* should be employed, but they materially add to the stability of the kite. The tension cords *t t'* are attached to the lower bars, *a''*, of the cells A A', and are connected by splicing or by a ring joint to the main cord T.

It will occur to any person of an adaptive turn of mind that a couple of biscuit-boxes, with one side removed and the others joined to form the apex of a triangle, might be connected by three light sticks, and the aforesaid experiment be simply and easily performed.

It must be understood, however, that even a toy must, to give satisfaction, be made to endure, and therefore we recommend the cane frame and varnished calico. Further, no box or cellular kite can be made effectively under 6 sq. ft. of surface, unless very strong winds prevail during the trial. The very trifling cost and simplicity of the box kite here shown should by its success lead to the construction of the more practical devices described hereafter.

In order to clearly understand the nature of "aërial stability" it is well that the amateur "kitist" should make up one or two sets of the box kites before attempting the really practical apparatus forming the true subject of our work. The rectangular form of double cellular kite (Fig. 2) should be at least 2 ft. square, and with these dimensions the frame, of split cane (Fig. 2*a*), need only embrace the outer case (*c d e*), the sides being made of cardboard 5 ins. wide. This is glued around the frame by linen strips (*f*), and the crossbar (*r*) connecting the two cellular kites is carried by a light stretcher (*g*) of brass wire. A swivel link should be used to connect the cord with the crossbar (*r*). The other shelves (*h i j k*) are half slit, as shown by Fig. 7, and linen corners are glued upon the junctions. In order to avoid splitting the cane forming the outer frame, it is better to cross the members with short projections, and brace them firmly

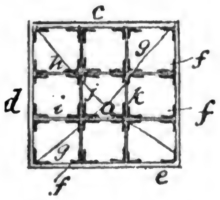


Fig. 2*a*.

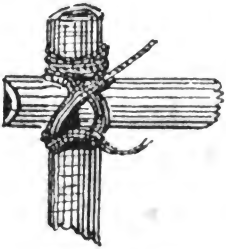


Fig. 6.

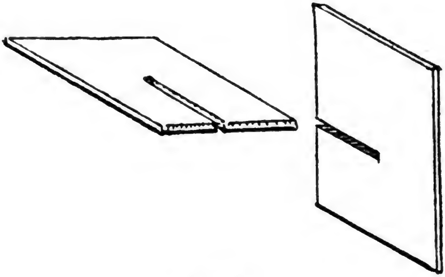


Fig. 7.

crosswise, as in Fig. 6, using strong thread, and afterwards soaking with thin glue. The entire surface within and without should be sized, and after drying receive two coats of copal varnish. If it be desired to use the kite frequently as a single kite, or one of a series of tandems, it is advisable to add a third coat of varnish.

When using this form of kite, which I may say has been found to be of high efficiency by the inventor, Mr. Hargrave, and Major-General Baden-Powell, the problem of stability without a pendulous balance, called a "tail" or a weight, will be at once apparent to the veriest tyro. And this structure forms the basis of a far more imposing apparatus, which may be adapted to manifold purposes. There are inherent difficulties in the way of really practical balloons and airships not to be overcome by the amateur scientist, however great and accommodating the means at command. But a kite is like an aërial yacht: although the area of navigation is circumscribed by the length of the fulcrum cord, the frame, material, handiwork, and usage are all within the reach of a moderate purse and a fair general knowledge of the use of tools, with common sense as a natural adjunct.

We have in mind a kite or aëroplane 16 ft. in height and 10 ft. across its major dimension. We have therefore to take into consideration a real force, and deduce the real proportions of each part in detail, from the size of the cable to the frame, fabric, and stays. The force exerted by even a light breeze upon an opposing surface is not generally known, and therefore a table within kite-flying range will be useful for reference :

Light air current	0·004	lbs.	per foot.
Light wind	0·125	„	„
Light breeze	0·246	„	„
Moderate breeze	0·406	„	„
Fresh breeze	0·983	„	„
Strong breeze	2·00	„	„
Moderate gale	2·98	„	„

It follows that an area of 10 sq. ft. must be so loaded and of sufficient strength to sustain a wind pressure varying between 0·05 lb. and 2·89 lbs. In designing the structure of a large kite the Hargrave cellular system cannot be implicitly followed any farther than to provide a sufficient cell area on each side of the fulcrum to preserve the equipoise, which must be supplemented by wings. A certain degree of flexibility should obtain in the construction of these, because we know that the air currents when flowing at a rate of five or more miles per hour do not maintain a level course, but are sinuous, like sea-waves—of greater height and depth in the case of strong winds because of the lighter nature of the disturbed medium. The wings, therefore, must be capable of a "give-and-take" movement, which is automatic, and only to be attained by the employment of pectoral stays of sufficient elasticity.

Bamboo, if obtainable and if of good quality, is undoubtedly the best material for the frame of a kite. But at the best it is not reliable, being subject to a dry rot at the joints, which is not externally apparent, but soon causes a collapse under an imposed strain. It is also impossible to obtain a length of 16 ft. of 1¼ in. in diameter intact. One or more sleeve joints must be interposed. I prefer, however, to substitute drawn steel tube ¾ in. in diameter, well known to autocar and cycle builders ; and when we come to work out the relative weight and strength it will be found to be better than bamboo at its doubtful best, and very little, if any, greater expense—and, taking into account the increased facilities for making the required joints, it will be satisfactory all round.

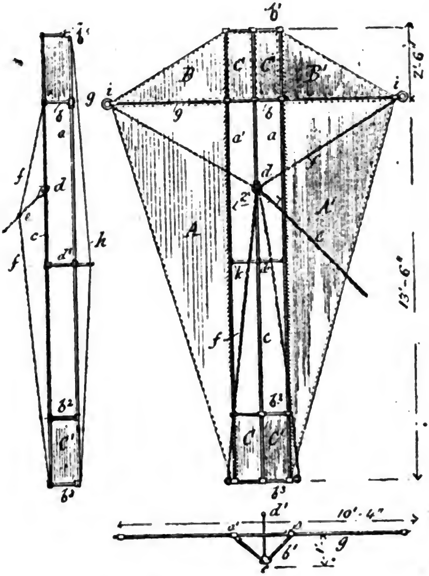
Premising this, we will set out the frame upon a drawn steel tube basis, afterwards showing the substitution of bamboo and larch.

CHAPTER II.

AS we now contemplate a structure the calibre of which is beyond that of a toy, the primary consideration is to ascertain the limitation of pressure to be withstood, and the load to be borne. That the necessary strength should be attained with the minimum of weight is, of course, a desideratum. The special kite forming the subject of the following description may be conceived by the elevation (Fig. 12), side view (Fig. 13), and top plan (Fig. 14). Here we have two vertical rods (*a*, *a′*) with a cross-yard (*g*), and a cutter-bar (*c*) in front of all, joined to *a*, *a′* by triangular frames b, b^1, b^2, b^3, which are enclosed by fabric to form upper and lower triangular pockets, the sides of which form wedge-sails, or, more properly, "equilibrisers." The main sails (A, A′), top sails (B, B′) and pockets (C, C′) present an aggregate of 74 sq. ft. as an area of resistance to the air current, and support for any weight carried over and above that of the structure itself. This means a total pressure in pounds under varying conditions of wind currents as follows :—

Light wind	about	98	lbs.
Strong breeze	„	150	„
Moderate gale	„	220	„
Heavy gale...	„	750	„

Therefore, taking the range from 50 lbs., which will barely raise the structure, our aërial yacht should sustain a varying strain of from 50 to 1000 lbs., which is ample for all purposes. The tension rope (*e*) and slings (*f*) should be suitably proportioned. As a framework throughout, combining strength, elasticity, and lightness, drawn-steel tube cannot be excelled. This may be obtained from any of the "Cycle Supply" firms, or motor-car makers, and the preferable size is



Figs. 12, 13, and 14.

¾ in. The weight of this runs at 0·4 lb. per foot, which totals—

Frame (*a*, *a′*)	12·8 lbs.
4 triangles	4·8 „
Cross-yard...	4·0 „
Cutter-bar	6·4 „
Stays (*d* and *k*)	1·6 „
15 couplings	2·75 „
5 eyes	0·8 „
Total weight frame	33·15 lbs.

Then comes the added weight of the sails, 74 sq. ft.:

Dressed calico	41 lbs.
„ silk	30 „
„ duck	49 „

So we may estimate the working weight to be about 80 lbs., exclusive of the weight of the tension rope and slings. The supporting value of the kite is very closely reckoned in the case of a light wind. Here is an instance in which the value of two or three box kites arranged tandem-wise, as previously shown, is not to be despised. In light winds, an increased area divided into sections and having each an independent equipoise, although with the same angle of tension, affords a better support than that of a single kite of the same area—that is to say, upon the lines as just now described. Later, we may deal with kites of more complicated structure, and requiring greater skill in manipulation, in which these conditions are subject to considerable modification.

In constructing the frame the tee-joints (Fig. 15), elbow-tees (Fig. 16), and eye-sockets (Fig. 17) are preferably cast in clean sand, if home-made, with a minimum thickness of metal $\frac{3}{32}$ in., which allows of a certain amount of trimming. The alloy should be ternary, viz.—

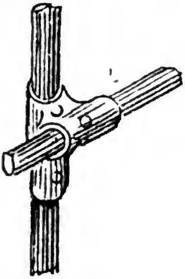


Fig. 15.

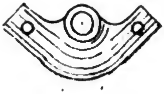


Fig 16.

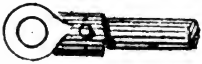


Fig. 17.

Aluminium	6 parts,
Copper	60 "
Zinc	30 "
Tin (only added for screw-cutting) ...	4 "
	100 "

which has a tensile strength of 86·4 per square inch.

The fit upon the tubular members of the frame should be fairly free, to allow of brazing without filling the bend with brazing spelter. The joint must be manipulated in the fire to prevent this waste taking place, by keeping the surfaces to be brazed dead in the heat zone and approximately level. Small $\frac{1}{8}$-in. pins, slightly split at the point, must be inserted at each side of the joint as shown, the holes being drilled after brazing, and made to correspond, as a driving fit, not a splitting fit. The elasticity of the metal will cause the split ends to expand sufficiently, if they are allowed to project, to prevent withdrawal. Three or four pieces of fire-brick, or gas-stove asbestos blocks, make a good hearth for clean brazing, a charcoal fire being placed upon them, and the nozzle of the household or other bellows inserted to maintain the draught. In the case of the house-bellows it is well, in order to avoid domestic complications, to protect the end of the nozzle by a *tuyère* of pipe, larger than the nose. The spelter is made as an alloy, cast into sticks, and if these are small, fed into the interstices of the joint to be brazed ; or the sticks may be granulated by a coarse file or rasp, and the filings mixed with the flux. The spelter is, preferably, as follows :—

Aluminium	20 parts,
Copper	10 „
Tin	60 „
Silver	10 „
Zinc	30 „

and the flux is—

Copaiba balsam	3 parts,
Venice turpentine	1 part,
½ spoonful lemon-juice,	

and must be kept in a free liquid state for application. In brazing of this description, nothing equals a gas blowpipe ; but if this is not available, the other device will serve the purpose. In all cases of using aluminium in an alloy it should be added last, after the other metals are melted, and perfectly liquid in consistency.

No further reference need be made to the joints,

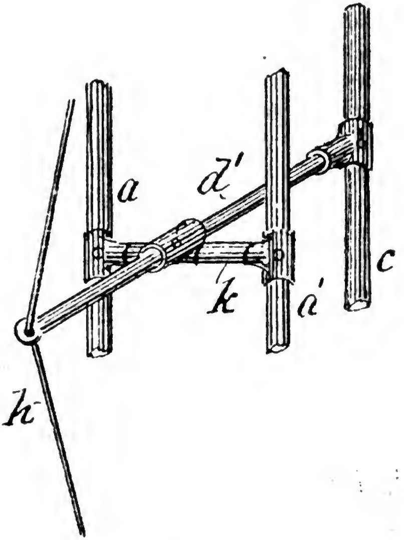


Fig. 18.

except to mention that as the $\frac{3}{4}$-in. tube is usually made in 4, 6, and 8 ft. lengths, the frames (*a*, *a'*) and cutter-bar (*c*) must be provided with a longer sleeve than usual to the tee-joints connecting *d'* and *k*, as shown drawn to a larger scale (Fig. 18).

It is apparent to even a casual non-scientific observer that the weak part of the frame is in the longitudinal space between the upper and lower triangular cross frames. Hence the adoption of the central transverse tubular strut (*d′*) and the cross-bar (*k*) between *a*, *a′*. The strut (*d′*) is flattened, welded, and drilled at the end to carry a wire stay (*h*) attached to the bottom and top of the frames, and stretched tightly over the strut. The size of the wire is No. 12, S.W.G. Delta metal—this particular alloy, when drawn into wire, being admirably adapted to the purpose. A coupling-link, or shackle, may be interposed, to enable the tension to be adjusted and maintained, preferably a double-ended pin or spindle, with a right and left handed screw-thread engaging with two links, or shackles, respectively. The "leeches," or free edges of the sails (A, A′, B, B′), are double-stitched around a leech-rope ($\frac{1}{2}$-in. manilla), the ends of which are spliced into an eye and left projecting for attachment. The edges next the spars are hemmed by double-stitching, and eyeletted at distances of 6 ins. with $\frac{3}{16}$-in. brass eyelets. Through these the lace cord is threaded, and over and under the spar. The slings (*f*) attached to the cross-yard (*g*) pass through a ring at *e*, and terminate at the rings forming the lower extremities of the frame *a*, *a′*. A fair size for these slings is $\frac{3}{4}$-in. manilla, with spliced ends. The tension-rope is fixed to a ring (*d*) freely sliding upon the cutter-bar (*c*) and passing through the loose ring at *e*, and should be 1-in. dressed manilla for rough winds, and $\frac{3}{4}$-in. for light breezes. It is understood that the dimensions of ropes and cords refer to circumference, and not diameter. Sufficient length should be allowed in the slings (*f*) to admit of the final adjustment of the angle according to the weight. It may be estimated roughly that, in the case of a kite of this kind, the lifting-power is about ·632 of the total number of pounds' pressure exerted upon the surface, according to the power of the wind current. Hence, referring to the tables, a moderate gale will be necessary to lift a person weighing 10 stone, plus the weight of the kite. Nevertheless, it is practicable, and, for other scientific purposes, eminently adapted under most conditions of weather. Any weight carried, photographic camera or the like, is supported within the lower triangular pocket. A windlass of simple construction, with proper appliances for anchorage, will be subsequently described in its proper place. Whether weighted heavily at the lower end or slightly, say 8 pounds, for purposes of equipoise, the peculiar structure of this kite causes it to maintain an equable position, rising and floating majestically in the air without plunging or dipping.

It is only fair to the late Mr. Breary to state that the actual design of a triangular kite with central aperture and upper and lower pockets is due to him, as the originator. Every type of structure or mechanism has its particular sphere of usefulness: this is a universal law, therefore applicable to kites as well as other things; consequently, as we go deeper into the subject, always from a constructive point of view, the evolution of the aëroplane as a flying-machine will be dealt with. Such evolution may be instanced in this case, as in others which need not be particularized, by the elimination of the tail in constructing a practical kite.

CHAPTER III.

THE transition from a structure based upon an inclined plane, as described by the previous chapters, to a multiple aërocurve system needs a preliminary explanation.

We have referred to the Hargrave system of "boxing," but to explain in brief the action of a curved surface must resort to a familiar analogy. In a tidal river each bend between points is termed, in boating parlance, a "reach." Now when the tide is flowing swiftly as a powerful current in one direction in midstream, it is possible to utilize "back water," or reflex current, in exactly the opposite direction, close in shore, and so travel by tidal action against the tidal current. This is obvious, if we consider the projecting points of land between the limits of the "reach" to be curves, and the reflex, or back water, to be proportional to (*a*) the original central tidal current, (*b*) the dimensions of the curve, and (*c*) the area of the floating body. Applying the analogy to kites and aëroplanes, we have to take the direction and power of the wind as the direct current, and utilize the reflex from one or many curved surfaces to the best advantage. We talk and write of "against the wind," and so far as a kite, aëroplane, or any appliance operated upon or subject to the air current, termed "wind," is connected with the earth or water, it is correct, even if the connection be only a kite line. As we advance, however, to modify our aërocurve kite to act as a weight-carrier independently of the cord, so that it becomes a true aëroplane, we shall see that even a strong gale is, as it were, still air, except in its relation to the earth.

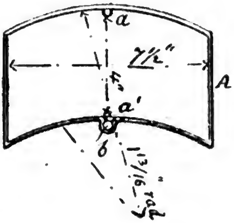


Fig. 19.

We show a frame (A, Figs. 19 and 20) of our multi-cellular kite, which can be made to the dimensions shown, or these may be doubled throughout. Umbrella rib steel of U section meets the requirements as to the maximum of strength and minimum of weight for the larger and smaller scales. The joints should be brazed, and a templet cut, with the proper radii set out as shown, in order to assure the perfect alignment of the whole multi-cellular structure.

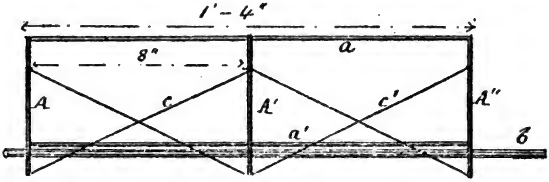


Fig. 20.

In a following chapter a true, or approximately true, cissoidal curve is described, but in this case the arrangement of the cells allows of the tangential action of the wind current through the steps or grades being sufficient for all purposes when ordinary radii are used in striking the individual curves.

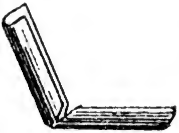


Fig. 21.

Previous to bending, the U rods should be annealed by heating cherry-red, and plunging into sifted ashes, bone dust, or sand, until cooled. Then the corners may be nicked by a three-cornered or saw file, as Fig. 21, bent round the templet, tapped to close perfectly, and when the templet is removed the junction should be brazed by a blow-pipe and ordinary brazing solder. A ring of No. 20 S.W.G. serves to hold a $\frac{1}{4}$-in. bamboo, which should be 3 ft. 8 ins. in length, to couple each pair of cells. Three frames, as shown by Fig. 19, are used for each cell, or forty-eight in all. The longitudinal members, *a a′* (also of U steel), are brazed to each

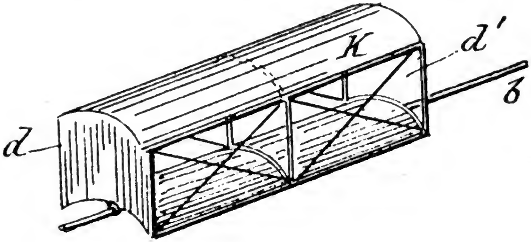


Fig. 22.

frame, and cross ties, *c c′* (of Delta metal wire, No. 24 S.W.G.), are twisted and plain soldered at the corners, as shown by Figs. 20 and 22. It is essential that in order to produce the best effect the surfaces must be polished, unwrinkled, and not distorted in any way. It will be noticed on referring to Fig. 22 that the top, and bottom, and end (*d*) are covered, and *d′* (central space between each pair) left open. The proper method of procedure is to bend a sheet of tin conforming to the curve, and laying upon it a sheet of thin calico previously pierced for stitching or lacing upon the frame with stout thread. Then a coating of starch mixed with 8 per cent. methyl alcohol is painted well into the interstices between the threads, and allowed to dry under heat. When sufficiently stiff, a light coating of collodion solution on the outside renders the covering air and weather proof, and the shape is maintained. Each pair of cells (K K′), with the open ends (*d′*)

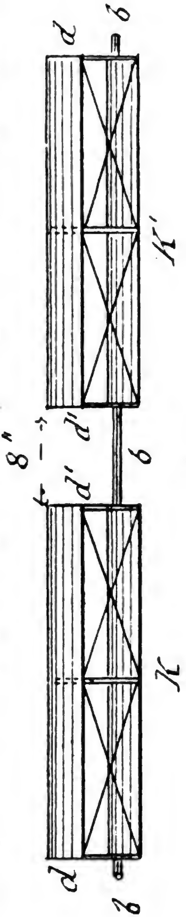


Fig. 23.

opposite, are fitted upon the bamboo coupling (*b*), as shown by Fig. 23, the space between being not less than 5 ins., and not more than 8 ins. for the smaller size dimensioned on the drawings. The joining of the sets of cells is effected in this space by means of No. 18 S.W.G. Delta metal wire, in the manner shown by Fig. 24. The ends of these wire links are twisted round the bamboo couplings *b*, and the ends soldered to prevent untwisting, and yet allow of a certain freedom of motion. So, when not in use, the upper sets (K, K‴, etc.) may lie upon the lower set; but when in the air the proper position is assumed automatically. The tension cord is duplicated, one end being attached to the coupling bar of K, and the other to that of K″, the single tension leading to the winch having a ring at *e* 3 ft. 6 ins. from K″, through which both cords may move. It is better to make this connection with a double turn round the ring *e*, to brake down a too free movement, which may disturb the equilibrium. The length of the series of

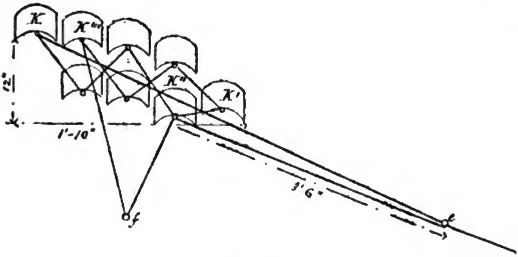


Fig. 24.

cells K is 1 ft. 10 ins., and the height, when in tension, 1 ft., the width being approximately 3 ft. 6 ins., as Fig. 23. The weight suspension at *f* is attached to K″ and K‴, and the angular arrangements of the suspensions, connecting links, and tension cord must be carefully followed.

We may now calculate the efficiency of this multicellular kite as a weight-raiser and sustainer under different conditions of wind pressure.

The aërocurve surface of each cell is: $8 \times 16 = 128$ sq. ins., or 256 sq. ins., per total effective surface, top and bottom. Therefore, each pair equals 512 sq. ins., as Fig. 23; and $512 \times 8 = \frac{4096}{144} = 28{\cdot}4$ sq. ft. The weight of each cell should be 3·5 ozs., or total, including rings *f* and *e*, unloaded, 5·5 lbs. Referring now to the wind-pressure table (Chap. I.), we find the third grade "light wind," necessary to raise the machine, and the sixth will sustain 56 lbs. at *f*.

Following the relative proportions exactly, but doubling the dimensions, we obtain $32 \times 16 \times 2 =$ 1024 sq. ins. per cell, and $1024 \times 16 = 16{,}384$ sq. ins., or 113·7 sq. ft., and the weight approximately 15 lbs. Now, with a light breeze, this will raise about its own weight; and with a strong breeze, 212 lbs. at *f* above its own weight.

The strain upon the tension cord may be safely calculated at one-sixth the lift. Taking the maximum at $\frac{340}{6} = 56$ lbs. (about), we find a ¾-in. manilla cord has a working strain of 60 lbs., which appears to fit the requirements. To be on the safe side with the largest dimensioned kite, a 1-in. manilla may be chosen. The measurement of rope and cord is always in terms of circumference; so the respective diameters are approximately $\frac{1}{4}$ in. and $\frac{3}{8}$ in. The weight of the $\frac{3}{4}$-in. cord is, when dry, 0·021 lb. per foot; and the 1-in. cord 0·03 per ft., or 30 lbs. per 1000 ft. All the rings and joints should be "long spliced," or the amateur "kitist" may have a practical illustration of the travelling properties of an aëroplane when free from the cord before the force of gravity terminates the voyage.

It is obvious that a kite having a probable pull of the value of 56 lbs. is not to be held like a schoolboy's toy. Therefore a winch like that shown by Figs. 25 and 26 should be used. It is, of course, not absolutely necessary to slavishly follow this especial method of construction, but it will be advisable to note the salient features of the device. A piece of $1\frac{1}{4}$-in. gas-pipe (B) should have a long gas thread cut at each end, and a thin nut run up to the end of each thread.

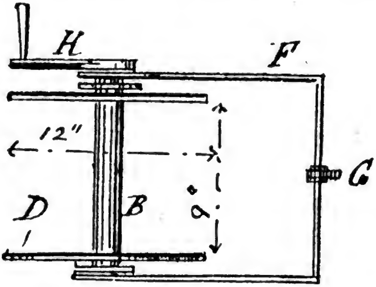


Fig. 25.

Two discs (D) of $\frac{1}{8}$-in. gauge zinc or $\frac{1}{16}$-in. sheet iron should be centrally bored to fit tightly upon the tube, and pushed or tapped up to abut upon the nuts. Then a lock-nut should be screwed tightly upon each end of the pipe, to firmly press the discs home and hold them firmly. Then two standards (I) of $\frac{1}{2}$-in. round iron should be slightly flattened at one end, and turned round into an eye to form a bearing for the pipe-spindle (B). The free ends of each standard should be welded to a trifurcated pointed grip-holder, preferably of steel, so as to allow of being driven into and firmly holding the ground. One standard only is formed with another eye (*h*) carrying a stud which forms the fulcrum for a foot-brake (*k*), with a lever (*j*), which, when depressed, forces a hard-wood block (*i*) against the edge of one of the discs (D). This is merely a precautionary arrangement, since in general use the thin edge of the disc would rapidly cut through the block (*i*), but for the occasional service required the hard-wood brake-block is sufficient. A hole (*l*) in the disc allows of the introduction

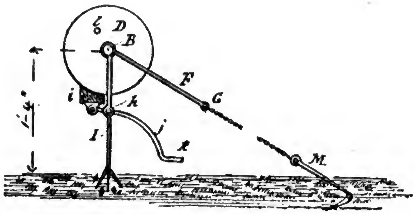


Fig. 26.

of a stop-pin when the kite is soaring at the required altitude, which holds the tension cord by contact with the standard (I) or frame (F). The standards (I) are pushed upon each end of the pipe-spindle (B) next to the nuts. Then a rectangular frame (F), with two bearing eyes formed at each end, is placed in position outside the standards (I), and the pipe-spindle projects on each side. Upon one projecting point a handle (H) is fitted by a pin, or screwing, and upon the other a lock-nut, which should be prevented from unscrewing by means of a burr upon the outside of the thread. These bearings should be free. A link (G) on the back bar of F carries a cord or chain of sufficient length to permit a simple flat fluke grapnel or stockless anchor (M) to be inclined to obtain a good back grip. The angle should be less than that of the tension cord to be efficient. So far as described, the device is a very simple bit of blacksmith's work, and by no means clumsy or costly. It is possible, however, to make a winch of wood which will answer the purpose, but it must be borne in mind that a long back grip is indispensable unless a clear open space is always accessible, when a post, or fixed frame with a sound foundation, may be permanently established. In calculating the requisite diameter and width of the drum, the diameter of the barrel (external) is 1½ in., and the diameter of the disc 12 ins., the circumferences being 37·6 ins. and 4·7 ins. respectively. Then $\frac{37\cdot6 + 4\cdot7}{2} = 20\cdot6$ ins., the mean circumference. Using cord ¼ in. diameter, $4 \times 9 = 36$ layers wide, and 11 layers deep = 396 coils 20·6 ins. in length, or approximately 680 ft. Such a length would mean an altitude of about 180 ft., but the dimensions of the barrel may be modified to accommodate a greater length. It must not be forgotten that our previous calculation shows that 680 ft. of this kind of cord weighs, dry, 14·28 lbs., which is a factor to be considered as a deduction in the weight-lifting estimate.

When well made, this form of kite is undoubtedly the best for experimental purposes. It is absolutely stable in soaring, and, by reason of the concave undersurfaces, displaces the air slowly if overloaded or when the wind pressure falls, so that its descent is after the manner of a parachute.

If any one cared to take the trouble to buy or make a pair of narrow hand-rollers, the framework could be made of sheet aluminium, and the primary weight thereby reduced; and the Pegamoid Co. make a stout "map linen" that will take the collodion solution without the preparatory starch treatment, and, whilst possessing the same tensile strength as calico, is 18 per cent. lighter.

The necessity for following the rules for coupling and shaping the curved surfaces cannot be too urgently insisted upon if the reader desires to achieve success. Nor can it be too strongly impressed upon the amateur "kitist" the fact that the conditions of the atmosphere at various altitudes, relatively to the earth, are such as to afford different degrees of electrical potential, and therefore it is of great importance to secure a metallic connection with the earth when metal wire or stranded cables are used for the tension-cords of kites or aëroplanes. The mere anchoring of the winch may not suffice, especially if the ground be dry. If it be possible to lead a wire from the tension or the winch-frame to a water or drain-pipe, it is wise to do so. An electrical discharge is likely to take place even under a clear sky, which may result in a severe, if not a fatal, shock. The remedy is to provide a metallic path to a sufficient area of earth to dissipate the current sent up by the difference of potential.

CHAPTER IV.

A KITE, or captive aëroplane, is subjected to two diverse strains, viz. the "waftage," or drift, which represents the tendency to travel with the wind, and the "lift," or vertical pull. The ascension of a cellular kite, similar to that described in the previous chapter is limited to the angle assumed by the tension cord when the vertical pull is from 5 to 5½ times the pull upon the tension cord. This is based upon the presumption that the kite is not loaded, or merely sustains its own weight. Now, the vertical pull, or lift, may be much increased if the planes are curved, so as to present an edge to the wind, and a concave surface to produce a reflex action. Before describing the structure of an aërocurve kite, or system of aërocurves forming an aëroplane, it will be well to test the value of such a curve as shown by Fig. 27, in which the direction of the wind current is shown by the arrow, and A is the aërocurve, W a suspended weight, and R a flat rudder, or cutter. The weight (W) is suspended from the curved edge at *b* and stayed at *a*; and its action is slightly oscillatory when starting, and during the continuance of the flight of the aërocurve *against* the wind. This small experiment illustrates Hargrave's theory of "aspiration." The term is somewhat misleading, but nevertheless it serves the purpose as well as any other. The initial impulse is due to the momentum imparted to W, and it is obvious that the "soaring," "gliding," or "aspirations" ceases when equilibrium is restored. Meanwhile a considerable flight may be attained with a moderate air current. It follows, therefore, that if we provide a system of such aërocurves in a suitable manner to utilize the pressure of the air current to the best advantage, we may construct a serviceable kite for high altitudes. If we arrange a series of such aërocurve surfaces behind each other relatively to the air current, it will be found that the foremost surfaces are performing a greater amount of work in "lifting" than the rearmost surface. This is because the foremost plane is always meeting and destroying the inertia of the air current in doing work, and the reflex action consequent thereupon is

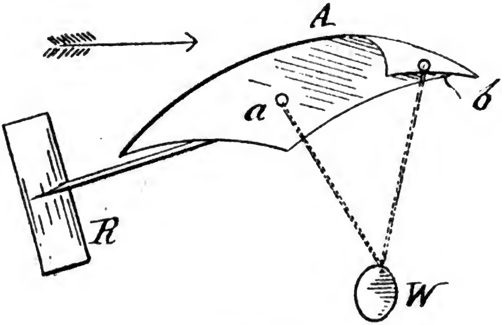


Fig. 27.

to produce a downward current, the following surfaces riding upon air, the inertia of which has already been disturbed. Now, it is our province to design a kite in which the curves are so shaped and arranged as to perform an equal amount of work in proportion to their surfaces throughout. The first point is the construction of the aërocurve as a single plane opposed to the air current; and, secondly, the disposition of such curves, with due regard to the "lift" and "waftage," or "drift." A wing feather of a soaring bird is a perfect example of a system of aërocurves, presenting a surface which, by direct and reflex action, utilizes the air current *against* its direction, which appears to be a paradox until carefully considered, and against the depression due to gravitation. Our aërocurve is best tried experimentally by bending a thin sheet of iron plate, and using it as a mould for the wire skeleton shown by Fig. 29. The actual bending of the mould should be accomplished by

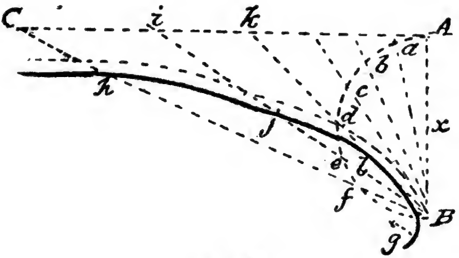


Fig. 28.

the aid of a template, the conformation of which is indicated by the diagram, Fig. 28. This is, approximately, a cissoidal curve, not absolutely correctly plotted, but sufficiently so for all practical purposes.

The cissoid probably furnishes the only bit of poetical sentiment in the prosaic ways of mathematical formulæ—so much so as to allow of a digression, to point out to the reader and student the straight, proper, and correct asymptote (AC), to which the curve from B is ever aspiring, ever approaching, but never attaining. The moral is left to the rational deduction of those who "read between the lines." Sufficient that a rectangle (CAB) is described where CA may be extended to any reasonable degree, but never less than AB × 2·29. Bisecting AB at *x*, a semicircle is described, the diameter equaling AB. From B as a centre, radians *a*, *b*, *c*, *d*, *e*, *f* are drawn, and prolonged

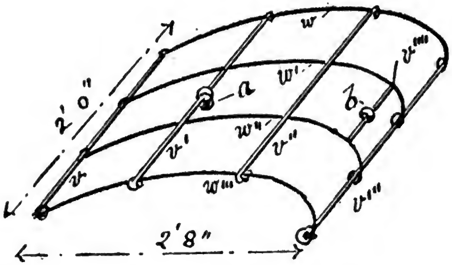


Fig. 29.

to cut CA as shown. Now, we have the points C*h*, *ij*, *kl*, wherewith to plot to curve. Then

$$kl = a\mathrm{B}$$
$$ij = c\mathrm{B}$$
$$\mathrm{C}h = d\mathrm{B}$$

and $hf = \mathrm{A}i$ merely as a matter of proof that the curve is correctly drawn. The terminal curve from the centre *g* is not arbitrary, but should be about $\frac{\mathrm{AB}}{6}$. It is obvious that the greater the number of divisions of the semicircle AB, and consequently the set-offs on CA, the more correct the curve will be.

There are many methods and multifarious ways of setting out curves, and in the author's experience each individual adopts a method of his own. The author's method is to construct the curve to full size on a sheet of drawing-paper well stretched by damping, and attached to the board by good gum around the edges. When dry a flat working surface is attained, and the curve may be plotted in pencil. It necessarily has a certain number of "flats," therefore a transparent sheet of celluloid, $\frac{1}{32}$ in. in thickness should be used to trace, and then cut out by means of a sharp penknife. The "flats" may be edged by the very careful use of a dead-smooth file, making the curve really curvilinear without spoiling its attributes. Then, when attached by light pins in the place of the constructed curve, the shaped edge may be used as a ruler for the drawing-pen. The celluloid sheet may be kept as a templet. It is understood that the use of the file is the longitudinal movement, with the file at right angles to the edge to be filed, technically known as "draw-filing."

We do not set out other than an approximate formula for its construction, but one essential feature must be maintained, and that is in the smoothness of the surface, which, with the use of mild steel or iron plate for the mould, should present no difficulty, and the whole surface should be kept slightly greasy, since it forms a foundation for soldering or brazing the frame shown by Fig. 29. This consists of four longitudinal curved members (w, w', w'', w''') of No. 16 S.W.G. steel wire, bent and soldered or brazed around the end transverse members (v, v'''), the intermediate transverse members (v', v'') being bent over w and w''' and soldered or brazed. A short transverse (v'''') is fixed between w' and w'', to carry a link or ring (b), to be afterwards described. The exact position of this short transverse (v'''') is determined by a line drawn from the centre (g, Fig. 28) parallel to the asymptote line (CA). A similar link or ring (a) is affixed to v' between w' and w''. Thereby we get a stiff frame, which, whilst still on the mould, may be covered with chart "pegamoid," or undressed calico, sewn round w, w''', v, and v''' *after* being varnished with one coat, another being applied after the stitching and contraction. The dimensions are shown by Fig, 29, and afford 6 sq. ft. of aërocurve surface. No doubt a novice would think the framework an unnecessary weight, but we have to take strength and durability into consideration, especially at high altitudes, for which this especial form of kite is designed to carry recording instruments, camera, and possibly signal-lamps.

Now, Fig. 30 is a section of one-half of a kite built up of eight aërocurves upon the lines set out. This represents 8 × 6 = 48 sq. ft. of surface, and taking into consideration the fact that an aërocurve based upon an approximate cissoidal curve is as 1·8 to 1 in efficiency relatively to a box-curve, therefore we may count on 3·9 lbs. per foot, or 187·2 lbs. total lift with a strong breeze.

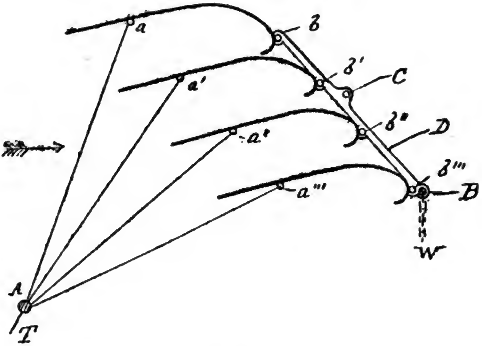


Fig. 30.

The four aërocurves are superposed as shown by Fig. 30, and the rings or loops (*b*, *b'*, *b''*, *b'''*) are joined by a plate (D) of aluminium sheet, with a bored lug at C for attachment to a ¾-in. bamboo rod, 5 ft. in length. A similar rod passes through the lower lug (B), and a 1¼-in. bamboo rod through A, to which the tension guy-cords are attached, proceeding from *a*, *a'*, *a''*, *a'''*. It will be seen that when two sets of such aërocurves are mounted upon the 5-ft. rods, the stiffness of the fabric depends upon the back plates (D); and since the width of each set is only 2 ft. there is an open space of 1 ft. between the pair, to which the single tension cord (T) may be adjusted so that both sets are in equilibrium. And similarly the weight (W) may be centrally suspended from the rod (B). It is preferable to bore the lugs at C and B sufficiently large to take a metal ferrule, soldered or brazed to the plate (D), and pinned to the rods. This form of kite is collapsible, until exposed to a free air current, and frequently requires an initial impulse, analogous to the schoolboy's run when starting the flight of his primitive kite. The forms of practical kites previously described do not require an initial impulse. If two persons uphold the kite by the back rods (C, B), and a cyclist holding the cord (T) loosely, that is to say, with but little tension, runs against the air current, the expanding area of the aërocurves will soon relieve the holders of the weight, and the slack of the tension cord (T) may then be controlled by the winch.

It will be noticed that although the curves are equidistant in Fig. 30, the small return curve *g*, which is not of arbitrary dimensions, is gradually closed from *a* to *a'''*, so as to allow of the free reflex action of the air upon the working or inner surface of each curve, that it may not impinge unduly upon the upper or passive surface of the next lower aërocurve. This is a matter of judgment.

When two sets of aërocurves are placed side by side as described, with a central tension and a central load, it might be imagined that a slight bend in the connecting-rods, so that the aërocurve surfaces are inclined upwards at an angle of about 5°, a "diedral angle," in fact, similar to that of the two wings of a soaring bird, would increase the effect. That is not the case in practice, and the apparent similarity of action is entirely different in the two cases. There is "volition" in the flight organs of the bird, although it appears to poise motionless in the clear ether.

In a following chapter we will take the kite built up of aërocurve surfaces as just described, and substitute a light motor between W and T, and then with a diedral angle between the sets of curves we shall imitate as nearly as possible the action of the soaring bird. But although this device is a flying machine pure and simple, it is not "practical," because the motor is of necessity so light as to soon lose its propelling power: nevertheless, it is an instructive and useful experiment.

The construction of the true aërocurve, as here laid down, is worthy of very careful study in view of the construction of a really useful practical kite.

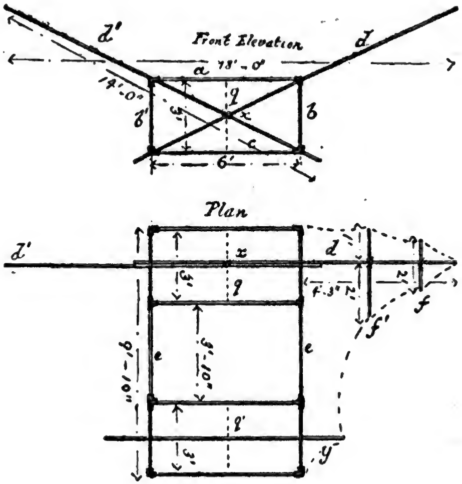
CHAPTER V.

BEFORE we enter into the wider range of self-supporting aëroplanes, it will be worth while to consider the adaptation of any of the types of practical kites described in the foregoing chapters to "steering and tacking" for sledge, carriage, and boat propulsion. There may be no bridges nor bars; a perfectly clear course is indispensable.

The box kite is obviously the best for obtaining a steady pull, but it requires modification in order to allow of the manœuvring necessary to maintain a straight water or road course independently of an angular wind. In fact, what is generally known as the "Cody" wing kite, as very successfully used by Mr. Cody, is the best for the purpose.

We have noted, in the case of the "Hargrave" box kites, the action of an air current both as an initial force and reflex force acting upon the surfaces of these chambers, and yet greater effect in vertical lifting when the surfaces are arranged as stepped aërocurves. But in all the cases shown and described, the force at disposal has been considered as at right angles to the face of the lifting surfaces; and the divided air current passing round the extreme outside edges has been counted as a negligible factor. But, given that the portion of the split or divided air current exerts a lifting force within the chambered spaces of the kite, it still has a direction imparted to it and derived from it, in the same manner as a stream of water with a certain force may flow through a pipe, and thereby derive a direction, if the pipe be fixed, and, if bent and movable upon an axis, divert the pipe. This is not a good analogy, but is the best to render the action of a steering aëroplane clear to the understanding of the novice. Since the direction of the chambered aëroplane cannot be diverted because of the "through current," we must take advantage of the split current on the outside of the chambers. In order to do this we have to provide wings (*d*, *d'*, Fig. 38) of stiff varnished calico, hemmed with whip-cord insertion, and stretched over the diagonal masts and yards as shown. If *n* be the "pulling" cable, *l*, *l'* and *m*, *m'* are guy-ropes whereby the aëroplane may be diverted from the line of the "through" current by the action of the "split" current upon the bat-like wings, the central current forming, as it were, an axis upon which the aëroplane may swing to "tack" from 15° to 25° from the normal wind current. Thus, for boats, carriages, or sledges, we are provided with a motive power that requires no renewal except when nature ordains a barometric depression. But, as we have said, there must be no bridges, bars, nor adjacent clumps of tall poplars, elms, and like impediments. It is not within our province to select the place, but to describe the kite, and how to make it in a practical manner. Our earth, despite the advance of civilization, has yet moors, sands, and broads where the kite-arëoplane may be safely used as an efficient motor.

There is in the market a good, sound bamboo, termed "Teraili," running about 1¼ in. in diameter for about 12 ft., then tapering off. The distinguishing feature of this cane is a kind of tortoiseshell mottle colouring. If it is fairly dry, it will weigh about 10 ozs. to the yard run. Without cracking the siliceous coating, it is advisable to pin-drill the joints or natural divisions, in order to ascertain if the interior decomposition known generally as "dry rot" has set in. If the fine drill powder is quite dry, with a fusty



Figs. 31 and 32.

smell, a slight bending strain will snap the cane at the joint. Parallel diameters should be chosen for the major part of the framework, but the diagonal masts (*d*, *d′*, Figs. 31, 32, 33, and 38) may advantageously be tapered, greater elasticity being obtained in tacking. The two box chambers are made by the cane rods (*a*, *c*), each 6 ft. in length, and the side bars of the same material (*b*, *b′*), each 3 ft. in length. The longitudinal bars (*e*, *e′*) are carried through, 9 ft. 10 ins. in length, so as to bear two box frames, each duplicated (as *a*, *b*, *c*), giving a depth of 3 ft., as shown by the plan (Fig. 32), a gap of 3 ft. 10 ins. being left between them. The joints are mitre-butted at elbows, as shown by the section (Fig. 34), which is drawn to an enlarged scale. The elbow (*h*) is cast of aluminium alloy, as described in Chapter II. of this work. The T-joint (Fig. 35) and ring cross (+) joint (Fig. 36) are similarly cast, with 1¼-in. cores, to fit the bamboo

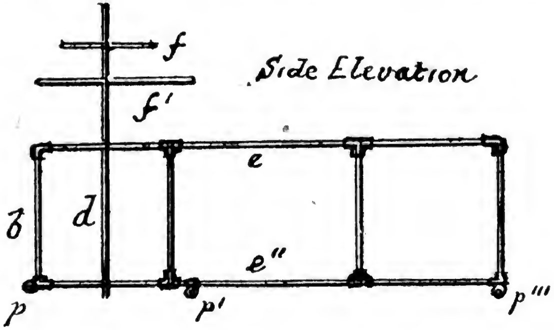
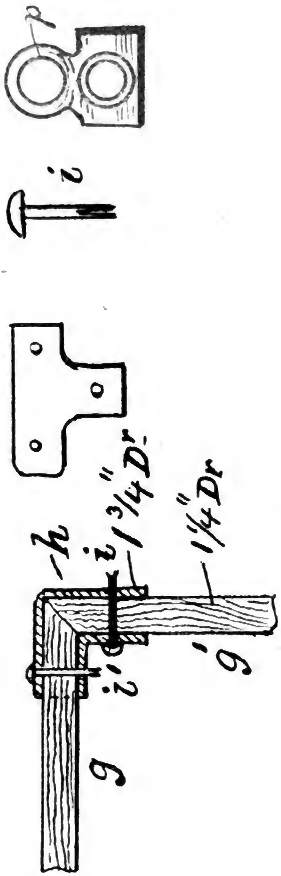


Fig. 33.

frame. Split pins (*i*, as shown by Fig. 36) are passed through drilled and *burned* holes in the cane, corresponding to those in the sockets. These pins are $\frac{5}{16}$ in. diameter, and are preferably of copper. The boxes or chambers (*a*, *b*, *c*) are divided by a mid-feather (*q*), which is stitched at the top and bottom with a whip-cord hem, and needs no frame for its support other than that of the members *a*, *b*, *b'*, *c*. The elasticity afforded by the free expansion of the fabric under the influence of side winds is of considerable use in assisting the wings during the manipulation incidental to "course tacking." The Figs. 31, 32, and 33 show the



Figs. 34, 35, 36, and 37.

disposition of the angular masts (*d*, *d′*), which are lashed at *x*, and the yards (*f*, *f′*) are also lashed to the masts. The yard *f* is 2 ft. in length, and is attached centrally; but *f′*, which is 3 ft. in length, is unequally lashed, so that 2 ft. of the yard extend on the after-side of the mast and 1 ft. upon the foremost side. A light mast (*y*) passes over the top of the rear box or chamber, and the dotted outline upon the right-hand side shows the outline of the whip-cord hemmed wing vane. The whole arrangement is, of course, duplicated upon the other side, but not shown. Back stays (*k*, Fig. 38) will be found

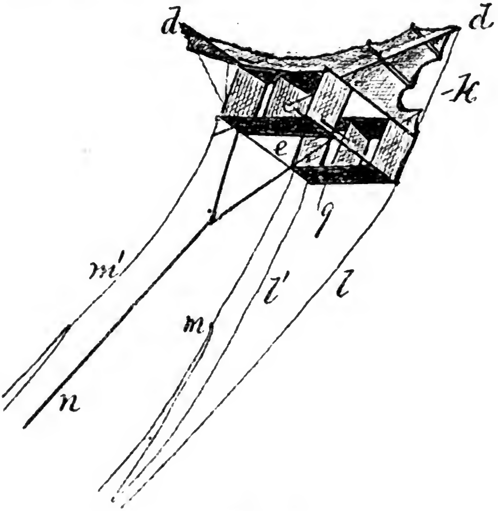


Fig. 38.

necessary to relieve the strains upon the extended masts (*d*, *d'*).

Now, this enormous aëroplane may seem to be too large an order for the ordinary amateur, but it must be remembered that it may be scaled to lesser dimensions, taking into consideration that the efficiency as a weight-lifter, or propelling power, diminishes as the square of the linear measurement. Here we have 72 effective feet of box surface, with a lift of 132 lbs. with a wind 1760 ft. per minute, and when the angular wings are allowed as haulage, neglecting vertical weight, the pull upon *n* (Fig. 38) is approximately 200 lbs. In water this will move a boat of tolerably fine lines, carrying twenty passengers, at a speed of six miles per hour. A four-wheeled carriage with pneumatic tyres, upon a level macadamized road, in dry weather, should carry six passengers at a normal rate of twelve miles per hour. It is obvious that a resistance to motion must be maintained, even by the use of a brake; or, in the case of a boat, a drag or "sea-kite"—*i.e.* an inverted bag, stretched upon hoops, immersed and towed. There is a distinct relation between altitude and resistance, and a free aëroplane must descend. At the same time, if the boat or carriage be steered so that the aëroplane has an angular pull within the prescribed limits by the manipulation of the guys (*l*, *l'* and *m*, *m'*), the resistance is naturally increased without the extraneous assistance of brakes.

If a wing cellular kite be used for signalling, a set of electrical lamps should be arranged upon a frame of predetermined shape and pattern, and the wire cable *n* may be used as a common return or "earth" connection, a terminal of each incandescent lamp being electrically attached to it. One or more of the guy-ropes (*l*, *l'*, *m* and *m'*) may be multi-stranded insulated cable, and terminate at a peg switchboard, which is connected to the source of the electrical current, such as an accumulator set or primary battery. The return or "earth" wire may be taken from the winch-frame to one terminal of the source. Now, if the peg board be made to correspond to the lamp frame, any pre-arranged luminous sign may be projected at such an altitude as to be visible for many miles round. In daylight automatic drop-shutters may be drawn down, each by its own electro-magnet, controlled by the peg board before referred to. This combination may constitute a signal system, to be read off by a telescope or binocular.

In cases where a great length of tension cord *n* is employed, smaller box-kites may be affixed at intervals throughout its length to materially assist in supporting its weight. This auxiliary aid is rather the exception than the rule.

It is an essential feature in the building of large aëroplanes to secure elasticity without slackness—that is to say, a rattling or shaky fit in the tee or elbow joints; good thread-sewn hems around a continuous length of whipcord is necessary, which must be spliced and trimmed instead of knotted at junction of ends. Any slight tear or rupture of the fabric will inevitably extend across the sheet under the pressure of the wind current. Therefore a nail jag should be carefully darned before an ascent is made. The initial start of a large aëroplane is not difficult if there be some willing and handy "holders up" available. The surfaces should be inclined to face the wind at about the angle that will be naturally assumed in ascension, and two or three persons may run against the wind with the slack loop of the tension cord that is left free from the winch. The assistants holding the aëroplane must, at the same time, take great care not to allow it to drag upon the ground, but must assist it to rise, and loose it when the independent support of the air current is felt. The weight-carrying capacity varies according to the wind pressure, and should be very carefully ascertained by dummy weights before one risks a personal ascent. And on no account should vertical weight-lifting be attempted when the air currents are intermittent or gusty, as the continued disturbance of the equilibrium of the supported aëroplane may cause it to descend violently and damage the structure. A steady breeze or light gale is everything that may be desired, and an increase of pressure up to 35 miles per hour will not be excessive.

The back stays (*k*, Fig. 38) are not arbitrary, but may be multiplied and modified to suit different conditions of strains, and may be of Delta metal with brazed eyes. This is preferable to any kind of rope or cord for rigging, since when once stretched it is not readily disturbed by humidity, and very slightly by variations in temperature.

In a personal ascent it is best to have a double-sheaved block attached to a light wicker-basket chair, and an ascent of at least 75 ft. attained before the chair is "taut." Then the tackle may be manipulated, and the aëroplane drawn down to the chair, until the forces are balanced, and the latter is raised with the aëronaut seated therein. Then the tension cord may be gradually released and the requisite altitude attained. Like many other feats, a certain command of nerve power is indispensable.

CHAPTER VI.

NO thinking person can use a stable kite or aëroplane similar to those described in the foregoing articles without devoting much solid consideration to the tension cord factor in the series of forces combining to raise and sustain a certain weight. Taking it as it appears to an unscientific mind, it is a comparatively useless tie to the earth; if it were non-existent, the aëroplane might soar onwards over hill and dale to the infinite horizon. The initiated know, however, that the free flight would be a mere trajectory, terminating in an ignominious dive earthwards.

Scientifically, a kite or aëroplane is acted upon by three distinct forces, shown by the arrows on the diagram, Fig. 43. These are: the air current, or wind pressure, Q, acting upon the inclined surface K, the tension cord P, and the action of gravity in the direction W. Now, we have seen that the stability of a kite or aëroplane depends upon its ability to move around the winch, or earth end of the tension cord, and thus always present the same edges and surfaces to the wind, no matter how the direction of the air current may vary relatively to the cardinal points of the compass. But, as we have seen, the tension E must obtain, or the angle of K cannot be maintained, and the equilibrium of the aëroplane is lost. We have established the fact that a kite-aëroplane, or, more properly, a captive aëroplane, may be utilized to raise and sustain a considerable weight. There have been various attempts to construct an aëroplane air-ship provided with motive power. Sir Hiram Maxim made the largest of these, and in the experiments it was mounted upon a track, and when sufficient horizontal velocity had been attained, a vertical ascension was achieved, but necessarily restrained, and limited to a few feet only. This result was astonishing, because of the enormous weight thus raised. The insuperable difficulties were in the necessity for a considerable length of the track to attain the horizontal speed required for ascent, and the provision of a second track upon which to alight and bring the machine to rest, and, above all, the maintenance of stability during flight. Therefore, for all practical purposes of aërial navigation, this magnificent and costly experiment was useless, except that it caused the clever inventor to concentrate his attention upon and produce the lightest power plant extant. And there have been many other motive aëroplanes, all having propellers arranged to produce a vertical and forward horizontal motion.

It occurred to the writer a few years ago to experiment upon an aëroplane fitted with a propeller in such a manner as to afford a retrograde movement in an angular direction. A very simple motor was used at first, and this is shown in front elevation by Fig. 39, plan by Fig. 40, and back end elevation by Fig. 41, Fig. 42 showing the application in a side view.[*] Referring to these drawings, A, A′ are two end plates connected by bolts, B, B′, passing through tubular distance pieces. A slotted holder, *h*, with a set screw, *i*, passes through A by a turned and shouldered spindle, carrying a ratchet wheel, *d*, and terminating in a square to enable it to be rotated by an ordinary clock key. The tension upon the ratchet *d* is maintained by a pawl, *e*, kept in place by a spring, *f*. A

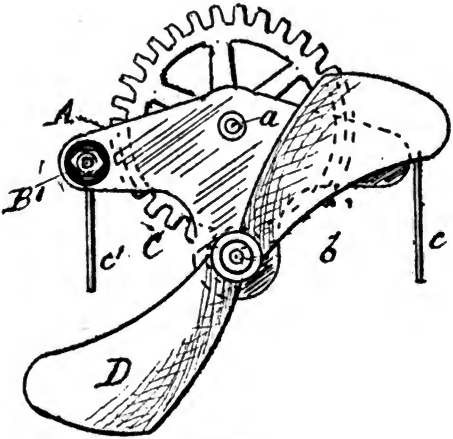


Fig. 39.

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[*] As the proportions of the motor may be varied according to the size of the aëroplane to which it is fixed, no dimensions are given.—F.W.

similar slotted holder, *h*, with a set screw, *i'*, passes through the opposite plate A', and carries a spur wheel, C, driving a pinion, *b*, the ratio being about five to one. An extension of A' carries one end of the

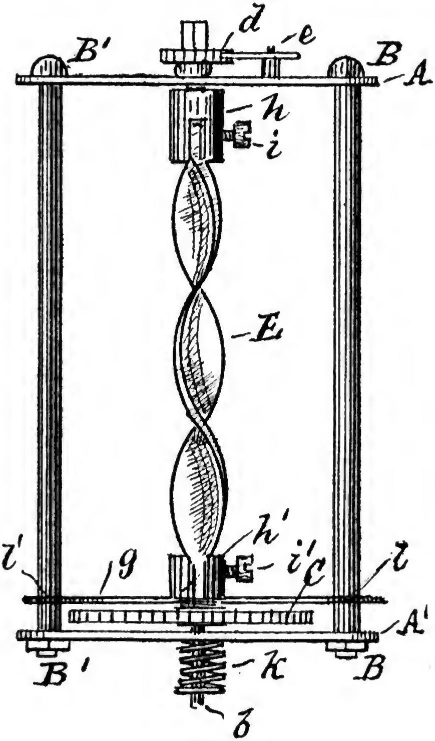


Fig. 40.

spindle *b*, the other rotating in a journal formed by the V-truss *g*, *g*, which is brazed to the tubular distance pieces. A collar is brazed upon the end of the spindle *b* inside the truss *g*, *g*, to take up the thrust of the propeller D, and a spiral spring, *k*, intervenes between A′ and the inner face of the boss of D. A stout strip of vulcanized indiarubber, E, of best quality, with no cracks or flaws, is easily fitted, with no longitudinal tension in the gaps formed by the slots in *h*, *h′*. Each end should be shielded on both sides by a small strip of leather, equal to the depth and width of the slots, and attached by indiarubber solution. By this precaution the rubber strips may be held firmly in tension by the set screws *i*, *i′*, without the possibility of flawing. Two wings or vanes of thin sheet metal, *c*, *c′*, are brazed upon the tubular distance pieces surrounding the bolts B, B′. A light metal fork, F, terminating in a ring, H, is riveted to each of the wings or

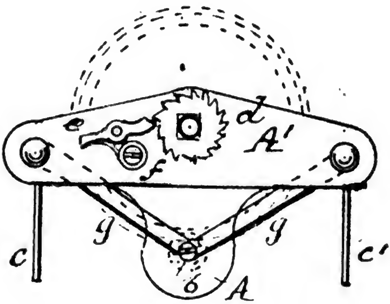
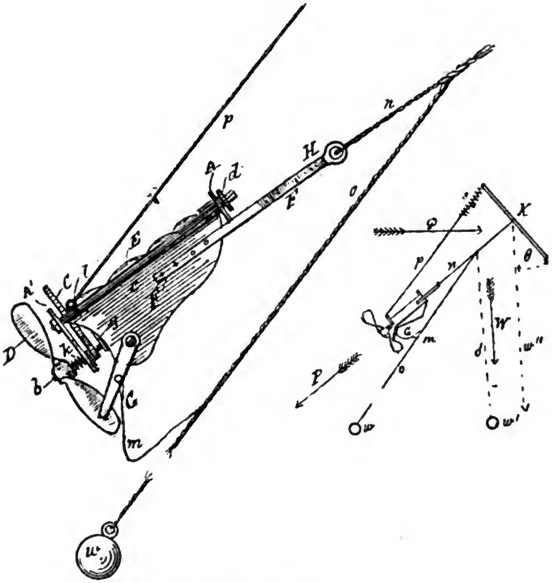


Fig. 41.

vanes, *c*, *c'*, and the tops of the **V**-truss *g*, *g* are also provided with small rings, *l*, *l*.

We come now to the propeller. A rather rough but sufficient calculation will enable us to estimate its



Figs. 42 and 43.

dimensions, to an approximate degree of accuracy that will serve the purposes of the amateur in his experiments. The circle described by the tips of the propeller should bear a proportion to the aëroplane area, thus—

Total aëroplane area, A
Area of circle described, *a*
Then $A \times 0{\cdot}216 = a$.

The angle of the widest portion of the blade relatively to the axis of the shaft should be approximately that of the tension cord relatively to the normal level, *i.e.* about 35°, and the area of each blade one-sixth that of the total area of the circle of revolution, A, as in the above calculation.

Up to 2 ft. 6 ins. in diameter, it will be sufficient to bend the blades out of a single piece of thin metal, leaving the boss intact, with a central hole, and brazing a collar on each side to make up the thickness, subsequently drilling and fitting a couple of rivets for greater security. For larger sizes, the angle should be marked out on the boss, and a frame made of umbrella U steel frame, bent to suit the pitch, and filled in with varnished calico, well stitched. It is preferable to use three blades in such cases, diminishing the area, so that in all the sum is one-third the area of the whole circle. Then the tips may be joined by a light ring or hoop, to prevent distortion. It must be remembered that the direction of rotation is opposite to that of winding the elastic band, E, and the screw propeller should operate in the direction of the arrow P (Fig. 43). The manner of suspension is shown by Fig. 42, and also by the diagram, Fig. 43.

Here we see that the tension cord proper, *n*, is attached to the eye or ring H at the junction of the light fork F. A guy or stay, *p*, is attached to each of the rings *l*, and also to the top corners of the aëroplane, which may be of any type previously described. In order to provide the requisite degree of elasticity, a spiral spring, *s* (Fig. 43), is interposed between the guys *p* and the aëroplane attachments. A catch or stop, G, is somewhat tightly screwed or pivoted to one of the vanes, *c*, so as to engage with the blades of the propeller D and prevent its rotation when the elastic band E is twisted and held in tension by the ratchet and pawl *d*, *e*. A false tension cord, *o*, is spliced to the tension cord proper, *n*, and terminates in a weight, *w*, which is sufficiently loaded to cause *o* to hang vertically when freely suspended, but not sufficient to act as an appreciable load, for the simple reason that its point of suspension at w' (Fig. 43) is in the wrong place, which for practical purposes should be w''. A cord, *m*, connects the catch G to *o*, and is long enough to allow *o* to hang vertically after the propeller is released by the withdrawal of the catch. We will presume the motor to be wound up and the angle adjusted. The initial flight is accomplished by a rapid retrogression of the cord *o* and weight *w*, and when the aëroplane is fairly launched, the weight *w* is released, and by its drop to the vertical the catch G is released, and the pull of the screw propeller D in its rotation fulfils the function of the tension cord, and an ascent is made until the motor is stopped by reason of the unwinding of the spring band. This should be accomplished in not less than 15 or 20 minutes, during which period a considerable ascent may be achieved. The vanes *c*, c' keep the motor always in a proper position with regard to the direction of the air current.

No practical purpose can be achieved by this experiment, except to prove to the veriest tyro that motive power may be applied to an aëroplane, or system of aëroplanes in tandem, to advantage, provided it be retrograde, and not progressive. Thus a field for sound scientific research is opened up, in which a thoughtful investigator may advance step by step towards the perfect aëroplane, that shall be no longer captive, nor dependent upon railed tracks for ascent and descent.

This is an age of light motive power, light fuels, and great economy in the efficient use of them; therefore, upon the lines laid down, there is room for improvement, and the means therefore are within easy access.

A diverted jet of gas or air, stored under pressure, would, if rightly applied, be far more efficient than a rotary motor.

It does not appear to be probable, according to the lights of revealed science and practice up to this present time, that the aëroplane alone under any conditions will constitute the future airship for passenger traffic, or as a weapon of offence or defence in war-time, but the combination of an aëroplane system with an aërostat of comparatively small capacity, not for raising more than one-third of the weight, but to establish a stable centre of buoyancy, will no doubt be *the* airship of the next decade. This, in combination with a propelling force that may act upon the air surrounding it in such a manner as to cause the subsequent reaction in the restoration of the equilibrium of the displaced gas, to be the real propelling medium.

A thoughtful man, of a scientific turn of mind and a certain amount of mechanical ability, may evolve the useful and practical out of the whilom plaything, the kite, with and without a tension cord, and if he does not find that the time so spent may be capitalized, he may console himself with the reflection that it has not been wholly wasted; it has afforded amusement to the individual, and probably added a step to the ladder that terminates in perfection. No really great or useful invention has been struck out at one blow by one person; it has advanced step by step, each enthusiastic inventor commencing where his predecessor left off; so, grade by grade, the boon in its entirety has been given to humanity. It is somewhat inconsistent, however, that in nine cases out of ten the last man gets all the credit and profit.

APPENDIX.

TABLE OF RELATIVE WEIGHTS OF MATERIALS USED IN KITE AND AËROPLANE CONSTRUCTION.

Material.	Weight in lbs. per cubic inch.
Metals.	
Aluminium	0·0926
Brass (Copper 80, Tin 20)	0·3124
Brass (Copper 70, Zinc 30)	0·2828
Bronze—Gun-metal	0·3145
Copper plate	0·3126
„ wire	0·3213
Delta metal alloy	0·2912
Iron, cast	0·2610
„ wrought	0·2817
„ wire	0·2811
Magnesium	0·6331
Steel plate	0·2823
„ wire	0·2838
Tin, pure	0·2637
Zinc plate	0·2422
„ wire	0·2613
Dry Woods.	Pounds per cubic inch.
Alder	50
Ash	52
Bamboo	25
Terail	20
Beech	48
Cherry	44
Chestnut	33

Material.	Pounds per cubic foot.
Dry Woods (contd.).	
Elm	41
Filbert	37
Spruce fir	32
Hemlock	23
Juniper	35
Larch	34
Oak	54
Poplar	41
Pear	23
Tamarack	23
Willow	30
Solids and Semi-Solids.	
Beeswax	60
Gum-arabic	90
Gutta-percha	61
Indiarubber	56
Sheet Material and Fabrics.	Pounds per square foot.
Cotton (calico)	0·0381
„ (dressed)	0·173
Pegamoid	0·1032
Silk (undressed)	0·0175
„ (dressed)	0·048
Wetalaine	0·0398

WIND PRESSURES.

Miles per hour.	Pounds per square foot.	Character.
1	0·005	Hardly perceptible.
2	0·02	
3	0·045	
4	0·08	
5	0·125	Breeze.
6	0·181	
7	0·246	
8	0·321	
9	0·406	
10	0·502	
11	0·607	
12	0·722	
13	0·848	Fresh breeze.
14	0·983	
15	1·131	
16	1·280	
17	1·452	
18	1·63	Gale.
19	1·82	
20	2	
22	2·43	
24	2·89	
26	3·39	
28	3·94	
30	4·49	
32	5·15	
34	5·82	
36	6·53	Stormy.
38	7·25	
40	8	
45	10·25	
50	12·5	
60	18·15	
70	24·6	Hurricane.
80	32·15	
90	40·5	
100	50	

ALLOYS.

Many references have been made in this work in respect of suitable metals and alloys, such, for instance, as "Delta metal." There are various grades of this alloy, each of which has its own advantages for a special commercial purpose. It may be briefly described as an alloy of zinc, iron, and copper, to which a certain proportion of phosphorus is added during fusion, and also lead, tin, nickel, and manganese; the best for kite and aëroplane construction is as follows:—

Iron	0·86	per cent.
Copper	55·80	"
Zinc	41·30	"
Lead	0·76	"
Manganese	1·30	"
Nickel	0·06	"
Phosphorus	0·01	"
	100·09	

In aluminium alloys we cannot get a good metal sufficiently elastic and ductile with a greater amount than 12 per cent. of aluminium.

Probably a 5 per cent. alloy is most suitable for our purpose in the jointing, thus—

Aluminium	5	per cent.
Copper	70	"
Zinc	25	"
	100	

This hammers well hot or cold, and, like Delta metal, does not rust, and has a tensile strength of 96 per square inch.

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